

USE OF INTEGRATED GPS AND GIS SYSTEMS IN MINE RECLAMATION

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ABSTRACT

Development of Global Positioning Systems (GPS) and Geographic Information Systems (GIS) has progressed to a point at which their sophistication and cost allow them to be effectively integrated in reclamation programs. This paper describes how these tools are being economically employed to inventory, prepare closure designs and reclaim former mine sites.

From the initial inventory of abandoned mine features through the closure of mines and mills, integrated GPS and GIS systems are playing an increasing role in abandoned mine land reclamation. The GPS system can provide state agencies nearly real-time data regarding the types and locations of abandoned mine sites through uploading of GPS data files onto an agency-accessible web site. The GPS data can subsequently be overlaid onto GIS maps to provide precise routes to, and locations of, those features.

The GPS surveying and GIS mapping allows rapid sizing and plotting of mine openings, waste piles and cultural features for accurate drawing and quantity computations during office design of the closures. Tied to state coordinate systems, the maps are accurate with respect to orientation and provide precise information for the preparation of construction documents. The GIS database provides streamlined storage of all pertinent information regarding the mine features including location, access routes, photographs and tabular summaries of dimensions, land ownership and notes regarding each location. Three-dimensional views generated by the GIS system can be used to illustrate the pre- and post-reclamation design features.

In the final construction phase of reclamation, the integrated GPS and GIS systems can similarly be used to locate the site, monitor closure during construction and provide as-built dimensions and documentation of closure within the database. It is the authors' intent to describe these capabilities and provide examples of their use in recent reclamation activities associated with the Star District mine reclamation project in Utah.

INTRODUCTION

Throughout the United States there are many thousands of abandoned mine sites posing potential hazards to the population. In the state of Utah approximately 4,000 coal and non-coal abandoned mines have been safeguarded to date¹. Yet, in this state alone, there remain an estimated 17,000 abandoned non-coal mine openings to be identified and potentially closed.

The cost of identifying, locating and compiling a database of these numerous sites has been greatly reduced by the integration of Global Positioning Systems (GPS) with Geographic Information Systems (GIS). The routes to, locations of, and dimensional data associated with, each mine site can be easily collected; the information can be electronically uploaded to a File Transfer Protocol (FTP) site while in the field, providing

office engineering and regulatory agency personnel nearly real-time access to view and evaluate the field inventory data and progress.

In addition to reducing site inventory costs and providing timely access of data to interested parties, the integrated use of these systems facilitates the negotiation of access agreements with landowners. The landowner can view the precise location of the hazardous mine on maps and, if needed, guide the landowner directly to the site using the GPS to view the hazard.

The easily accessible electronic GPS/GIS files continue providing efficiency during reclamation design and construction. During the design of the mine's closure, further savings are realized by the immediate availability of mine feature dimensions, orientation and photographs in the office. This information can continue to be shared with all interested parties via the dedicated FTP site. During the reclamation construction phase, the easy relocation of the site and documentation of as-built closure conditions further streamline the closure process.

This paper discusses an example of the use of the integrated systems during the state of Utah's recent abandoned mine inventory project in the Star Mining District, located in southwestern Utah.

ABANDONED MINE AREA

The Star Mining District is located approximately six miles west of Milford in Beaver County, Utah. Extensive hard rock mining has occurred in the mountainous Star Range from the late 1800's to today's presently limited mining activities. Minerals sought included copper, lead, zinc, turquoise, silver and gold. Hazardous features, including deep vertical shafts, horizontal openings (adits), trenches and highwalls frequent the area.



Figure 1 – Typical Vertical Shaft

The mined area is characterized by a semi-arid environment and fairly rugged topography, ranging in elevation from approximately 5,200 feet to more than 6,800 feet. Vegetation in the area is limited to cold desert shrubs (sagebrush) at the lower elevations to pinyon and juniper communities in the higher areas. The accessibility of many of the mine sites and historic features by established trails attract a variety of hikers, spelunkers, and off-road vehicles, necessitating the inventory of the sites for closure purposes.

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Sixteen land Sections, approximately 16 square miles, were investigated to identify the presence or absence of hazardous mine openings in the Star Mining District. A total of 198 mine features were inventoried over a period of 18 days. The inventory included locating, tagging, photographing and measuring each mine feature. Various inventory forms and engineering sketches were completed at each mine feature location.

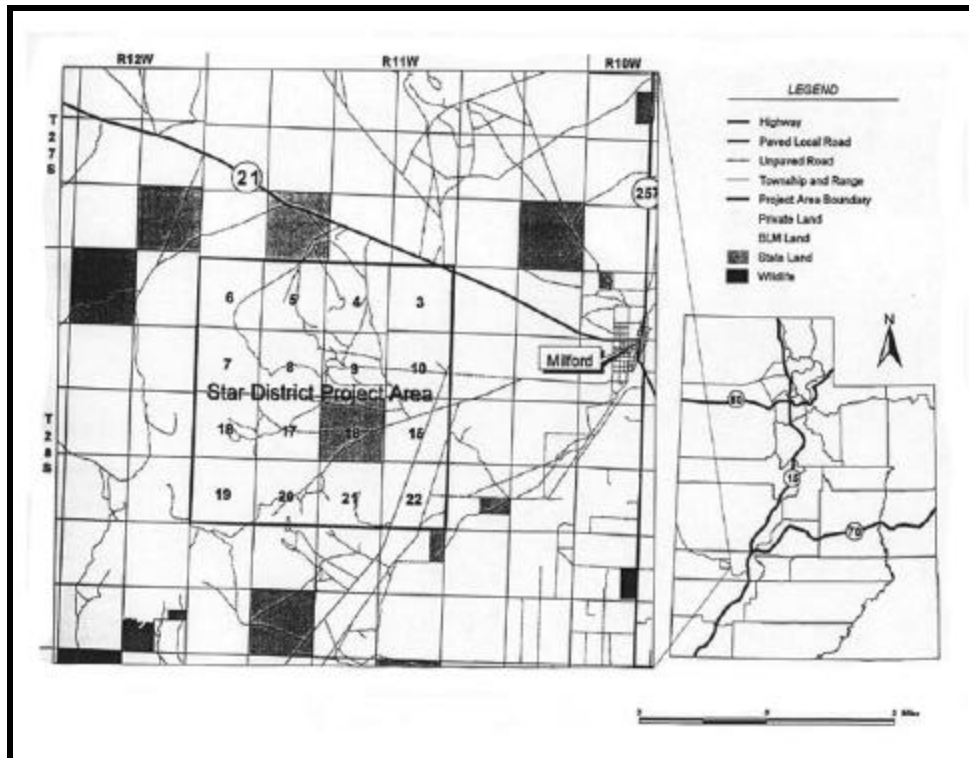


Figure 2 - Star Project Site Vicinity Map

The success of the inventory was dependent upon a methodical approach of inspecting this relatively large area. The similarity of the terrain throughout the area and anticipated large number of hazardous mine features made sole reliance on existing topographic mapping impractical and costly. Suitable means of conducting accurate field location surveys and storing collected data were necessary to:

- Identify locations of land Section lines,
- Find probable mine sites noted from the review of conventional topographic mapping and aerial photography of the area,

- Document areas that had been previously inspected and inventoried,
- Precisely locate previously unknown mine locations that were discovered in the field for tagging, photographing and measuring purposes,
- Electronically store, correlate and transfer collected data obtained from each mine site,
- Identify areas that remained to be inventoried, and
- Allow the inventory of mine sites to resume in the future where the previous inventory terminated.

To accomplish these objectives, compatible Global Positioning Systems (GPS) and Geographic Information Systems (GIS) were selected and employed. A Trimble Pathfinder® real-time differential GPS receiver (XRS) and a GPS receiver with post processing differential correction (GeoExplorer 3) were used to log the roads/paths to, and positions of, the mine sites. The inventory was thoroughly conducted using a combination of four-wheel drive vehicles, all-terrain vehicles and extensive walking routes.



Figure 3 - Trimble GeoExplorer3 (left) and Pathfinder (right)

A pre-defined inventory data dictionary was loaded into the GPS instruments prior to field use. The dictionary had three levels of information for field logging purposes, in a format consistent with ESRI's ArcView® 3.2a GIS software that was selected as the project's information database.

The data dictionary was first divided into the four basic features of "mine sites," "miscellaneous points", "miscellaneous polygons" and "roads." These were further subdivided into attributes, examples of which include vertical openings (VO's), horizontal openings (HO's) and prospects (PR's) for "mine sites" and four-wheel drive access, two-wheel drive access and walking routes for "roads." Data collected for the attributes would include information such as the directional bearings and dimensions of the mine openings.

Information obtained from the office review of U.S. Geological Survey (U.S.G.S.) topographic mapping, aerial photography and mine ownership records was also loaded into the instruments prior to conducting field inventory so that suspect mine opening

locations could be readily found and mapped, in addition to those previously unknown sites identified while in the field.

The actual field inventory was performed by a methodical inspection of each land Section typically progressing from the northwest to the southeast. Those Sections with the highest elevations and most severe topographic relief were mapped first due to access concerns during the winter season and the possibility of snowfall covering mine features. The GPS surveying of routes and mine locations was performed using four-wheel drive trucks, four-wheel drive all-terrain vehicles (ATV's) and extensive walking routes over steep terrain.

Each instrument's horizontal survey accuracy was checked between the two GPS receivers and with a permanent U.S. Coast & Geodetic Survey Benchmark in the field on a daily basis. All routes shown on existing U.S.G.S. mapping as well as newer roads and trails were surveyed within each land Section. Routes to each mine feature, as well as the precise location of the feature itself were recorded. Approximately eight to twelve mine features were located and inventoried each day, typically employing a three-person crew.

At the end of each day of field data collection, GPS rover files were processed for differential correction. This processing was accomplished using the U.S. Geological Service South Dixie Forest base station located approximately 50 miles south of the project.

Field personnel electronically uploaded corrected and uncorrected GPS files nightly to a File Transfer Protocol (FTP) computer server; the FTP site was remotely accessible by others. Files were uploaded in both uncorrected and differentially corrected, post-processed formats for access, review and comment by other home-office engineering and state of Utah AMR personnel. This process provided easy data access by all parties to review the field progress and comment on a near real-time basis. Data gaps and questionable field data resulting from the review could be addressed the following day in the field. The FTP site was structured, and data transferred, using Cute Pro 2.0 utility software.

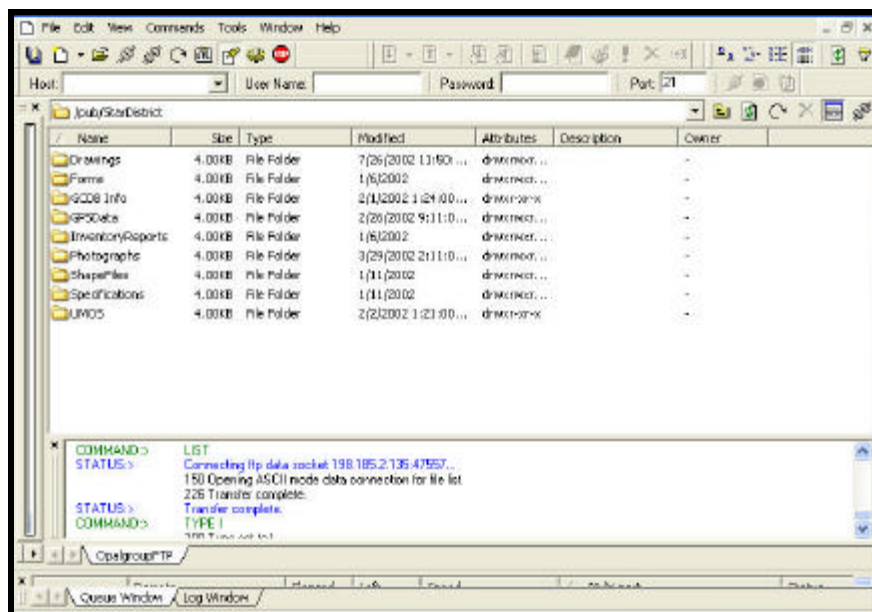


Figure 4 - Sample File Transfer Protocol (FTP) Site Structure

During the field inventory the daily GPS routes, mine locations and related field survey data were exported from the Trimble Pathfinder Office software and electronically converted to the form of a shape file (*filename.shp*). This file was subsequently imported into the ArcView® 3.2a GIS software as a GIS “theme” and superimposed on a Digital Raster Graphics (DRG) file of the area’s topography, using a common location coordinate datum.

Similar uploading of the ArcView® 3.2a GIS files to the FTP site was performed concurrently with the daily uploading of the GPS data files. The combined files were viewed in the home office as well as in the field to ensure the consistency of field data and plan the field inventory activities for the following day. The routes and sites plotted directly on the topography enabled the field personnel to plan their inspection routes on a daily basis and confirm that all areas of the site had been inspected.

Once the field inventory was complete, office design activities were similarly streamlined. Back-up files of all field data already existed by virtue of the daily transfer of data through the FTP site. The electronic data was employed during design by exporting the information into various engineering software packages, such as materials handling volumetric determination programs. For example, using a triangulation method program such as Trimble’s “Site Works” or AutoCAD’s “Civil Soft,” the materials handling quantities for available backfill from mine waste dumps were readily determined and viewed in three dimensions, if necessary.

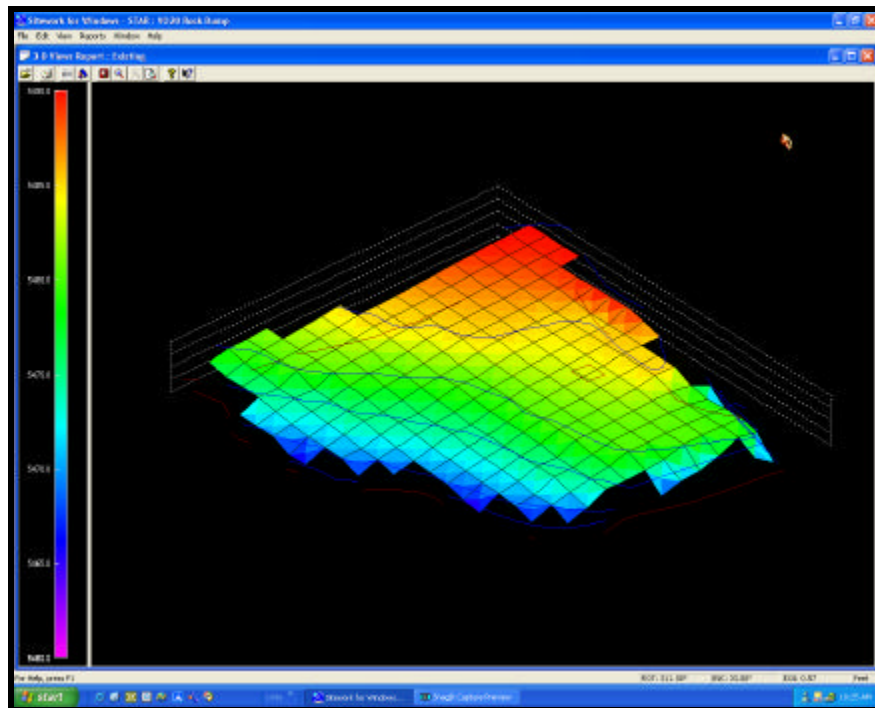


Figure 5 - Volumetric Determination Mine Waste Dump

Finally, the downloaded files easily form the basis for the reclamation construction document site location maps. The GPS/GIS data, when superimposed on the DRG topographic mapping files (as previously used in the field to confirm inventory

coverage), provides precise illustration of the location of, and route to, each mine site requiring closure. This information satisfies needs of the reclamation contractor to identify access to the site as well as the nature of the surrounding terrain for pricing purposes, since the contractor may not currently have the technical capabilities of electronically importing and viewing the GPS/GIS data.

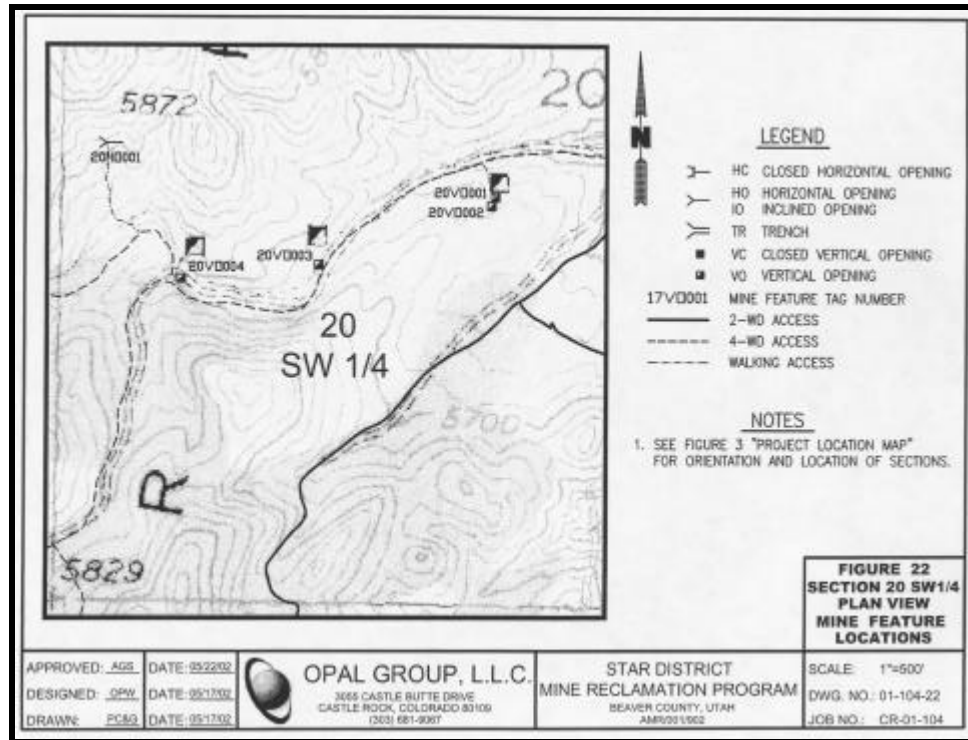


Figure 6 – Typical Construction Drawing Showing Mine Locations and Routes

SUMMARY AND CONCLUSIONS

The integrated use of GPS and GIS data provides significant savings of time and engineering costs during the inventory and closure design for abandoned mine sites. It is projected that the time required locating and logging inventory data associated with each mine feature has been reduced to one third or less of that required by more traditional and conventional means. The thoroughness and accuracy of the inventory provided by the combined technologies provides a significantly higher-quality engineering product. The transfer of data via an FTP site from the field to the office further provides a compression of project schedule along with an increased degree of accuracy provided by near real-time independent review of data collected in the field. The massive numbers of hazardous abandoned mine locations remaining to be inventoried and closed make the combined technologies a mandatory part of the abandoned mine reclamation program.

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REFERENCES

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